Transformative innovation in peri-urban Asia

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ABSTRACT

This paper draws on two case studies from India and China to discuss how and why rapidly urbanizing contexts are particularly challenging for transformative innovation but are also critical sustainability frontiers and learning environments. We argue that lack of understanding and policy engagement with peri-urbanization in its current form is leading to increasing exclusion and unrealized potential to support multiple sustainable urban development goals. Peri-urbanization is often characterized by the neoliberal reordering of space and a co-option of environmental agendas by powerful urban elites. Changing land-use, resource extraction, pollution and livelihood transitions drive rapid changes in interactions between socio-technical and social-ecological systems, and produce complex feedbacks across the rural–urban continuum. These contexts also present characteristic governance challenges as a result of jurisdictional ambiguity, transitioning formal and informal institutional arrangements, heterogeneous and sometimes transient communities, shifts in decision making to distant authorities and the rapid growth of informal market-based arrangements with little incentive for environmental management. These unique features of peri-urbanization may reinforce a lack of inclusion and hinder experimentation, but they can also present valuable opportunities for transformative innovation. This innovation is unlikely to follow the lines of niche management and upscaling but rather should take advantage of peri-urban dynamics. There are possibilities to build new alliances in order to renegotiate governance structures across the rural–urban continuum, to reframe urban sustainability debates and to reconfigure socio-technical and social-ecological systems interactions.

1. Introduction

In the wake of the industrial revolution the economist Henry George claimed "The association of poverty with progress is the great enigma of our times" (George, 1904). More than a century later, stark inequalities and poverty stubbornly haunt even the most advanced economies, while the devastating side-effects of rapid industrial development on ecosystems and climate are adding to a sense of failure of contemporary models of economic growth and innovation. In recognition of the need to grapple with the direction of innovation and socio-technical change as critical to a sustainable future (Martin, 2016; Stirling, 2008), there has been an associated shift in innovation policy thinking towards environmental and social justice (Schot and Steinmueller, 2016). For example, Zehavi and Breznitz (2017) argue for innovation policies that specifically address the redistributive effects of innovation, while Chataway et al. (2014) call for recognition of the role of the poor as both producers and consumers through a more inclusive conceptualization of the product and process innovation cycle. In recent years, the notion of "social innovation" has come to refer to "a change in social relationships, -systems, or -structures, … [which] serve a shared human need/goal or solve a socially relevant problem." (van der Have and Rubalcaba, 2016, p. 1932). While Bryden et al. (2017) argue for the importance of the concept of "inclusive innovation" which they define as "new ways of improving the lives of the most needy" (Bryden et al., 2017, p.7).

Following Bryden et al.'s (2017) definition of inclusive innovation, we begin with the premise that a fundamental and sustained improvement in the lives of the most needy will require new ways of individual and collective knowing, thinking, doing and being that dismantle myriad structures of social injustice, while simultaneously reconstituting a restorative relationship between social and ecological systems. These are systemic changes, which, as Leach et al. (2012) highlighted, involve active challenges to the direction of innovation trajectories, fostering a greater diversity of forms of – and participation in – innovation, and address the distributive effects of innovation in decision making.

Schot and Steinmueller (2016) bring similar perspectives to bear on innovation policy, stating that a "fundamental change in the socio-technical systems for food, energy, material, mobility, healthcare, and communication provision" is required (p. 16) along with the social-ecological systems with which these intersect. This system-wide change amounts to what Schot and Kanger (2016) call a Second Deep Transition, involving shifts in the direction of change across multiple socio-technical systems at multiple scales. Schot and Steinmueller (2016) argue that for such deep and wholesale changes to occur, a new framing of innovation policy is required that goes beyond innovation for growth

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and national systems of innovation to one of innovation for transformative change. This third framing of innovation policy acknowledges that ongoing processes of change and upheaval – e.g. creative destruction (Schumpeter, 1942) and destructive creation (Soete, 2013) – are part of the contemporary status quo, with politics and power shaping particular forms of progress. In the context of these processes of change a policy framing of innovation for transformation needs to focus "less on products, processes, firms and R&D, but on the achievement of systems wide transformations" (Schot and Steinmueller, 2016, p.16). This framing of innovation policy for transformative change shifts the focus to social and environmental challenges and places greater emphasis on the influence of poor (and non-elites in general) over the direction of innovation, as well as on a fundamental reconfiguration of the relationship between socio-technical systems and the environment from local to global scales. Schot and Steinmueller argue:

"It is important to stress that Framing 3 is not principally a model of science and technology regulation. Instead, it focuses on innovation as a search process, guided by social and environmental objectives, informed by experience and the learning that accompanies that experience, and a willingness to revisit existing arrangements to de-routinize them so as to address societal challenges. A claim underlying Framing 3 is that the innovation process is likely to be effective in achieving these goals if it is inclusive, experimental and aimed at changing the direction of socio-technical systems." (Schot and Steinmueller, 2016, p.18)

One of the most significant and pressing contexts for such systems-wide transformation is the contemporary phenomenon of urbanization (Ernstson et al., 2010). Processes of urbanization are implicated in worsening environmental degradation and poverty, while at the same time cities often drive growth and innovation (Ernstson et al., 2010). Bugliarello et al., 1994, p.135) noted that "the paradox of the large city is that, while its attraction for business, culture, and the professions is unsurpassed, the city is also unsurpassed in concentrating within itself the most difficult social problems of our time – poverty, disease, alienation, despair, neuroses, as well as social unrest and failures of complete technological systems."

David Harvey went as far as to conclude that "cities – those 'workshops of civilization' – are founded upon the exploitation of the many by the few. An urbanism founded upon exploitation is a legacy of history. A genuinely humanizing urbanism has yet to be brought into being" (Harvey, 1973, p.314). A central aspect of transformative innovation must be to contribute to the emergence of a more humanizing urbanism in the midst of the ongoing global urban transition.

In the global South one of the most important contexts of this urban transition is at the peri-urban interface, where there is a juxtaposition of rural and urban activities, and institutions and poverty, inequality and environmental degradation are often most closely associated (Allen, 2014; Marshall, 2016). The urbanization processes observed in rapidly developing countries across south and east Asia can be characterized as a self-reinforcing trajectory of exclusionary urbanization (see Fig. 1). This dominant trajectory is driven by a cycle of neoliberal restructuring of peri-urban space that facilitates the co-option of environmental agendas, exclusive urban greening and clean-up and control responses to the crises of rapid urbanization. This results in increasing exclusion from the benefits of urbanization and from urban policy processes. Many poor and informal urban and peri-urban residents face displacement and/or the exacerbation of environmental degradation and health risks associated with the negative impacts of urbanization. This is accompanied by increasing exclusion from political and policy processes that further reinforces the urban agenda of neoliberal restructuring.

These peri-urbanizing contexts can also present opportunities for alternative and more sustainable development trajectories, which are often neglected in formal policy and planning. For example, a plethora of local community-based adaptations and innovations emerge in response to a complex array of livelihood threats and opportunities that unfold in these dynamic and uncertain environments. As the current peri-urban becomes the new urban, there is a unique set of opportunities for rapid learning across the rural–urban continuum. We argue that the peri-urban is a critical frontier of sustainability (Marshall, 2016) and that peri-urban innovation processes, if appropriately recognized and nurtured, may hold the potential to be transformative and to challenge the dominant urban trajectory (see Fig. 1).

In the following sections of this paper we discuss this potential for transformative innovation in the peri-urban context in detail. In doing so, we examine Schot and Steinmueller's (2016) claim that innovation is likely to be effective in achieving the goals outlined in their transformative agenda if it is "inclusive, experimental and aimed at changing the direction of socio-technical systems". We bring together an emerging body of work in transformative innovation (Schot and Steinmueller, 2016) and insights from transdisciplinary studies on peri-urbanization, rural–urban linkages and potential pathways to sustainability in urban food, water and waste systems in the global south (Agarwal et al., 2015; Dolley, 2017; Marshall et al., 2017; Marshall and Randhawa, 2017; Priya et al., 2017; Randhawa and Marshall, 2014; Sharma et al., 2008). In section 2 we draw on empirical cases in India and China to identify and examine key features of peri-urban contexts that, we argue, are critical to understanding the challenges and opportunities for transformative innovation. Section 3 interprets the empirical cases and key peri-urban features we have identified, through a transformative innovation lens, and in section 4 we discuss broader lessons for transformative innovation research and policy.

2. Urbanization, peri-urban dynamics and sustainability

The following case studies were selected because they exemplify commonly observed features of peri-urban dynamics in rapidly urbanizing contexts. They also illustrate how these features can influence possibilities for transformative innovation in diverse socio-political and institutional settings such as India and China.

2.1. Case study background

Our Indian case study insights are based on empirical studies in peri-urban areas of Delhi's National Capital Region (NCR) and in Varanasi, Uttar Pradesh. The research has engaged peri-urban communities, local and international academics, local health professionals, activists, policymakers and planners in a series of projects that began in 1997. Through transdisciplinary initiatives the teams involved have collected biophysical data, conducted surveys and semi-structured interviews and carried out ethnographic and participatory research to examine the impacts of processes of urbanization, and specific mainstream development interventions, on the environment, and health and livelihoods of peri-urban communities. They have also highlighted interrelationships across time, space and social groups; for example, by examining how environmental degradation in peri-urban contexts impacts on food security and safety for residents in the urban core (Marshall and Randhawa, 2017). These initiatives have sought not only to increase understanding of rural–urban transformations, but also to support appreciation by diverse stakeholders of the possibilities for alternative, more sustainable, urban development trajectories and the mechanisms through which they might be achieved (Agarwal et al., 2015; Marshall et al., 2017). We have analysed how sustainability is defined and sought in urbanizing contexts (Marshall et al., 2009; STEPS Centre and Sarai, 2010), the social and political infrastructures that create and reinforce particular mainstream development trajectories, and the complex governance arrangements that influence outcomes for the environment and for poor and marginalized communities (Randhawa and Marshall, 2014; STEPS Centre and Sarai, 2010). A core area of focus has been on the impacts of urbanization on peri-urban farming communities, highlighting implications for food security and safety in the urban core. As part of this research, more than 1000 farmers in 28 peri-urban villages have been involved, with long-term participatory and ethnographic work at several sites. Working with

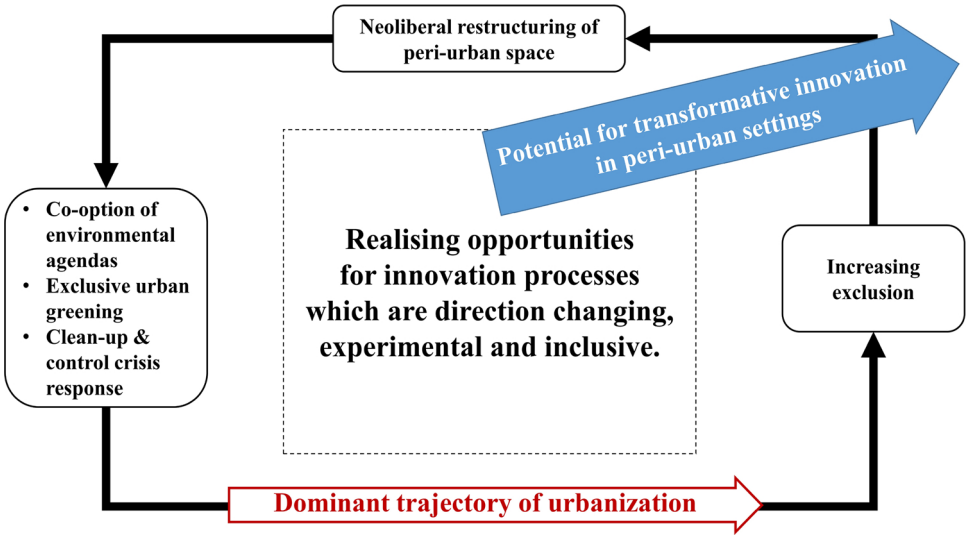

Fig. 1. Transformative innovation in the peri-urban context with the potential to challenge the dominant trajectory of urbanization.

community-based non-governmental organizations (NGOs), activists, policy advocacy groups and local officials, the teams have engaged with various routes for influencing policy and planning.

The China case study is based on PhD fieldwork in the city of Wuhan (Hubei province) between 2011 and 2012 in which a range of actors (farmers, distributors and officials) in the peri-urban vegetable production and distribution system were interviewed about the impacts of socio-economic, technical, environmental and policy change over the previous five years in Wuhan (Dolley, 2017). Interviews were conducted with three high-level municipal officials responsible for governing peri-urban vegetable production, 11 business people representing a range of larger scale commercial actors, 60 peri-urban farmers in 20 locations around the city and three local academics.

2.2. Peri-urban characteristics as contexts for innovation

Both the India and China case studies exemplify the peri-urban as a context of innovation in which a highly dynamic set of interactions between the social, ecological and technical elements of the system play out, with diverse consequences between social groups and across the rural–urban continuum. In rapidly urbanizing contexts, multiple processes of urbanization are simultaneously generating new opportunities while driving increasing vulnerability and negative consequences for marginalized groups and ecosystems. Within this wider context we draw further on the case study insights to elaborate three distinct features of peri-urban settings that, we argue, provide useful focal points for analysing the challenges and opportunities for transformative innovation.

2.2.1. Neoliberal restructuring of peri-urban space

Dominant patterns of neoliberal urban restructuring in both India and China have had major implications for peri-urban land use and livelihoods, and strongly influence the possibilities for transformative change.

Urban reforms in India unfolded (as part of the structural adjustment programme agreed with the International Monetary Fund [IMF] in 1991) under the aspiration of "world-class cities". Capital- and technology-intensive urban development plans were designed to attract foreign investment, business and tourism (Dupont, 2011). Processes of urban restructuring included the closure of industries and/or relocation from the urban core to the peripheries; demolition and relocations of slums; amendments in master plans for real-estate development for commercial (malls) and residential purposes; and deregulation and privatization of public utility services (Navlakha, 2000; Roy, 2004).

In China, following strict controls on urbanization under socialist industrialization (1952–57), chaotic "overurbanization" during the Great Leap Forward (1958–60) and the disruption of the Third Front Construction (1965–71) and the Cultural Revolution (1966–76), the reforms of 1978 set the course for a steady rise in urbanization (Ma, 2002), which has become the "most rapid, dramatic, and far-reaching process of urbanization in human history" (Simon, 2008, p.174). Throughout much of this process, migration to cities, has been tightly controlled through the household registration system (*hukou* system), which has enabled the state to largely prevent the proliferation of sprawling informal settlements common in other developing countries (McGee, 2008). Instead, the expansion of administrative control of cities over their rural hinterlands and the liberalization of land-use rights beginning in the 1990s has resulted in rapid urban expansion and redevelopment led by local municipal state actors through formal and informal, quasi-legal actions to transform rural hinterlands for urban land-uses, expand and relocate industrial zones to urban peripheries, and recreate the urban core as a centre of affluent consumption and commercial activity in a competition to attract global capital investment (McGee, 2008).

In both cases the ongoing transformations led by dominant trajectories of urbanization, rising land prices and competition for natural resources, leads to increasing uncertainty over the future of peri-urban space and livelihoods. In India, a common feature of urban restructuring is the displacement of communities and activities that are perceived as informal, undesirable or polluting to the periphery. Baviskar (2010) argues that this type of urban restructuring is an outcome of "bourgeois environmentalism", "where the middle classes try to pursue the creation of an ordered space…. where nature is controlled and made available for recreation". This type of restructuring tends to be very exclusionary, driving poorer groups from access to ecosystem services, urban services and political processes. An example of this can be seen in Delhi's National Capital Region, where there has been a forced removal of polluting industries from the most desirable central urban areas. Many informal or small-scale industries are clustered in peri-urban areas with weaker implementation of environmental regulations, resulting in overuse of scarce water resources and widespread environmental degradation. At the same time the expansion of urban markets has led to an increase in demand for peri-urban vegetable production. Currently, any support for agriculture tends to focus on elite commercial agricultural initiatives. This disregards the impacts of urban development and industrial pollution on widespread small-scale peri-urban crop production and the health and livelihoods of those (predominately poor and marginalized groups) dependent on it, and

also disregards the potential for alternative land-use strategies to combine urban development with improved environmental protection and food and water security to benefit all citizens (Marshall et al., 2018b)

In Wuhan the rapid redevelopment of urban areas and expansion into peri-urban farmland has driven a shift towards intensive vegetable production. In Wuhan, however, a large proportion of peri-urban vegetable farmers are migrants from outside the city who migrated with their families to escape rural poverty by growing vegetables for urban markets. They rent land from local farmers, live in informal housing on the corners of their rented land and depend entirely upon the sale of their vegetable produce in urban markets for their livelihoods. As the city expands these farmers are periodically moved on from their rented fields, losing homes, assets and receiving very little if any compensation for the loss of livelihoods. Meanwhile, local farmers (who collectively own the use-rights to the farmland) are able to benefit from the rental income, obtain employment in the expanding city and eventually receive compensation in the form of cash and urban property when their lands become redeveloped. Despite the role played by informal migrants, government policy provides no substantial support for their livelihoods and has instead been designed to promote the scaling up of protected, high-value and organic vegetable production by larger private or state-owned firms in order to increase control over the supply and quality of locally sold produce while also increasing exports to higher-value markets (Dolley, 2017).

This restructuring of peri-urban space driven by urbanization is closely connected to two further features of the peri-urban interface in India and China: the blurring of boundaries and the changing dynamics of socio-technical-ecological systems.

2.2.2. Blurring of boundaries

The peri-urban is a context where traditional institutions (rules, norms and standards) are weak or non-existent. Here there is a blurring of boundaries that includes, and extends beyond, administrative jurisdictions, formality and informality, justice and illegality and efficiency and inequality (Marshall et al., 2009; STEPS Centre and Sarai, 2010), creating both constraints and opportunities for transformative innovation.

As peri-urban spaces cease to be either distinctively rural or urban, institutionally and legally, they are often governed by complex administrative activities, and may fall outside the purview of both rural and urban governments (Marshall et al., 2009). In many Indian cities, bureaucratic oversight of the peri-urban is frequently non-existent for activities that do not fall into strictly urban or rural activities and jurisdictions. For example, our work in peri-urban Ghaziabad (Delhi NCT) demonstrated that agriculture that takes place in areas that have been formally designated as “urban” wards no longer receives support from the agriculture department (Marshall and Randhawa, 2017). There are also prolonged lag periods without formal governance arrangements, when villages that have been governed through the rural panchayat (local government) system are re-designated as part of an urban ward, requiring entirely different institutional arrangements, which are often developed in a distant place. In this “institutional vacuum” opportunistic behaviour emerges, albeit with actors with greater power having enhanced agency with respect to outcomes – informal land rental, and informal water extraction and treatment arrangements being ubiquitous. “Hidden” interactions and negotiations between the formal and informal system actors are responsible for securing the livelihoods of many, and may reveal important lessons concerning successful future interventions (Randhawa and Marshall, 2014). While some winners emerge, communities often have little choice but to resort to informal, illegal and often hazardous activities to secure basic services (STEPS Centre and Sarai, 2010), and the new informal markets that emerge to fill the gaps in provision have little concern for the environment.

This blurring of boundaries can also result in legal pluralism as both urban and rural laws and institutions are applied ad hoc (Dupont, 2007; Narain and Nischal, 2007). For many years in China, and more recently in India, peri-urban areas have been subject to new planning and control as a means to stimulate urban growth and economic development. As seen in the tensions in Varanasi and in Delhi’s NCT between retaining peri-urban agriculture and using land for urban development, the peri-urban is a highly contested space, in which risks and resources are distributed unevenly. There is an increasingly heterogeneous mix of actors with multiple and often conflicting interests including settled populations, in-migrants, transient workers, middle-class colonists, land speculators, investors, developers, informal industrialists/entrepreneurs, and local and municipal government. In Wuhan, increasing numbers of migrants in areas closest to urban sprawl live alongside the local villagers as second-class citizens with fewer rights and protections; their livelihoods are dependent on peri-urban farming, but insecure land leasing arrangements result in an ever-present possibility of displacement.

Recent research in peri-urban Delhi has highlighted the heterogeneous nature of communities and the likelihood of a lack of social cohesion; this adds to the challenges of addressing exclusionary urbanization, through difficulties in mobilizing people in response to environmental and poverty issues (Waldman et al., 2017). In addition, where local citizen activism is present, initiatives with a focus on environmental, health and livelihood issues of the poor tend to be isolated from each other.

2.2.3. Changing dynamics of peri-urban socio-technical-ecological systems

Interactions between human and natural systems are arguably at their most complex in urban contexts (Gaston et al., 2013). Once wild land has been converted to human-modified lands the changes continue. In peri-urban spaces, which we identify as having a juxtaposition of urban and rural activities and institutions (be they within the urban core or on the periphery), the use, appropriation, preservation or degradation of ecosystem services are being worked out in conflict, through negotiation or through chaotic evolution. The dominant trajectories of neoliberal restructuring and socio-technical regimes are resulting in a decline of ecosystem services (Marshall et al., 2018a) and a redistribution of the benefits of remaining ecosystem services away from the poor and marginalized (Section 2.2.1), while the blurring of boundaries (Section 2.2.2) ensures that environmental legislation and management is weak and challenging to enforce.

Systems of agricultural production and food processing, sanitation, manufacturing industries and waste disposal, drinking water provision, transportation, construction, housing and place-making (urban greening, parks, recreation, public spaces, cultural, religious) each collide and mesh with one another in unintended and often unpredictable ways. These interconnected socio-technical-ecological systems often comprise formal and informal elements in parallel or entangled systems, which frequently come into conflict over access to and quality of land and water and other environmental resources. This has important consequences for environmental and human health and well-being that are largely unrecognized and thus neglected in urban planning and policy. There are implications for multiple dimensions of poverty and ecosystem services, extending across space and time impacting multiple groups of peri-urban and urban residents. The temporal and spatially distributed nature of these impacts and lack of attention to the socio-technical-ecological interactions from which they result, makes solving them almost impossible within the conventional system of planning and policy making. Urban-centric infrastructure focused innovations promoted as urban development and improvement initiatives often target discrete symptoms or crises in a “clean up and control” mode while failing to address the larger interconnected problem of the economic development–health–environment nexus.

For example, in Wuhan the system of peri-urban vegetable production includes a diverse range of formal and informal actors and activities spanning urban and peri-urban areas. As a socio-technical-ecological system it is shaped most obviously by the continuing conflict

Table 1
Challenges and opportunities for transformative innovation in peri-urban settings.

		Inclusion	Experimentation	Direction changing
Neoliberal restructuring	Challenge	Exclusive framings of problems and goals of urbanization and disempowerment of peri-urban poor.	Those with power and resources best placed to exploit opportunities created by policy experimentation.	Changes in direction influenced by elite agendas in response to unintended consequences of urbanization rather than sustainability agendas.
	Opportunity	*Reframing urban sustainability:* Destabilizing incumbent socio-technical regimes and building new pro-poor environmental alliances in response to emerging shared risks. Reaction against elite agendas can strengthen demand for more radical experimental responses to emerging environment-heath-poverty issues. Alliances operating in policy, research, narrative building and planning arenas. Evolution of alliances over time, agile and responsive to rapidly changing political context.		
Blurring of boundaries	Challenge	Administrative ambiguity allows "organized irresponsibility" while formal urban plans and policies misrepresent the nature of informality and increasing heterogeneity in peri-urban communities.	Siloed municipal institutions and new formal institutional arrangements ignore or marginalize informal innovations and increase pressure on poor.	
	Opportunity	*Renegotiating governance arrangements:* Informal practices and relationships emerge across the formal and informal sector in the absence of effective formal provision, providing lessons for alternative governance arrangements. As environmental impacts reach across the rural–urban continuum and affect peri-urban poor and middle class, there is potential for new pro-poor environmental activism to mobilize marginalized communities, promote pro-poor experimentation and challenge the governance and direction of socio-technical regimes.		
Changing socio-technical-ecological dynamics	Challenge		Reactionary stance driven by rapid and unpredictable changes in socio-technical-ecological systems hinders experimentation.	Difficulty identifying complex causes of crises (time delays, invisible feedbacks, cross-scale interactions) encourage simplistic top-down clean-up and control responses from governments.
	Opportunity	*Reconfiguring socio-technical-ecological interactions:* Long-term engagement with peri-urban communities can provide rapid learning about the impacts of grassroots innovations and changing practices on trade-offs, synergies and feedbacks between socio-technical-ecological systems. This evidence can help challenge incumbent regimes and build a case for alternative and more sustainable patterns of urbanization.		

over land-use for urban development. This leads to the ongoing displacement of one of the most important, yet unrecognized, group of actors: migrant tenant farmers. The relatively short timescale (3–7 years) in each location that this imposes on these farmers increases pressure on them to maximize yields at the expense of environmental sustainability, since there is no incentive to maintain soil fertility or limit agrochemical runoff into surface waters in ecosystems that will no longer exist in a few years.

In Varanasi district and in peri-urban Delhi the relocation of polluting industries from the core of the cities, flows of urban waste from the city's core to the peripheries in the form of landfill sites and waste treatment facilities, illegal extraction of ground water by industries and disposal of untreated industrial and domestic waste in open space, under the ground and in rivers presents severe and long-term hazards to peri-urban ecosystems and human health (Agarwal et al., 2015; Marshall et al., 2009; STEPS Centre and Sarai, 2010). Weak environmental regulations and lack of pollution monitoring facilities and human resources in state pollution control boards results in a failure to address peri-urban environmental pollution (Karpouzoglou and Zimmer, 2012), which directly impacts on the health and livelihoods of peri-urban residents, while also adversely affecting the yield, nutritional quality and safety of food crops produced there (Agrawal et al., 2003; Marshall et al., 2003; Sharma et al., 2006; Singh et al., 2010b).

In Varanasi the research has shown how health hazards extend to those who might consume the produce grown on peri-urban smallholdings, including those who purchase from urban markets. For example, heavy metals, largely from peri-urban industries, have been found in produce from peri-urban areas, linked to both aerial contamination and uptake through soil contaminated with industrial wastewater (Marshall et al., 2003; Sharma et al., 2006; Singh et al., 2010a, 2010b; Singh et al., 2009). Peri-urban farming often involves reliance on recycled wastewater that is becoming increasingly contaminated, as traditional village ponds that were recharged by rainwater disappear in the development process, and other water sources become less accessible (Amerasinghe et al., 2013; STEPS Centre and Sarai, 2010). While at the same time other agriculture-related ecosystem services are degraded, and access by the poor and marginalized is increasingly restricted (Marshall et al., 2018a; 2017).

3. Opportunities and barriers to transformative innovation at the peri-urban interface

We began by asserting that the definition of innovation should be broadened in the way Bryden et al. (2017) suggest – to mean new ways of improving the lives of the most needy. We then argued that transformative change is required across multiple scales in socio-technical-ecological systems in which injustice and processes of environmental degradation are perpetuated (Schot and Kanger, 2016; Schot and Steinmueller, 2016). Based on these two claims, we interpret inclusive, experimental and direction changing to mean that the search process for the "new ways" that transformative innovation implies will be facilitated by policies that encourage the inclusion of diverse actors (particularly the poorest), open up spaces for experimentation to test alternative pathways of change, and break open the incumbent power relations that reinforce unsustainable and unjust socio-technical trajectories. However, understanding what inclusion, experimentation and direction change will really involve in a peri-urban context requires thinking through the particular challenges and opportunities for each in relation to the key features of peri-urban contexts outlined above. The following analysis takes each aspect of transformative innovation in turn (inclusion, experimentation and direction changing) and explores the challenges posed by different features of the peri-urban context (neoliberal re-ordering, blurring of boundaries and changing socio-technical-ecological system dynamics). This is followed by discussion of the opportunities peri-urban contexts provide for reframing urban sustainability, renegotiating governance arrangements and reconfiguring socio-technical-ecological systems. Table 1 provides a summary of the arguments.

3.1. Barriers to inclusion

The issue of inclusion is as much about who is involved – and on what terms – in the search for new ways of improving the lives of the most needy as it is about who defines the identity and interests of the most needy to begin with. The *neoliberal restructuring of peri-urban space* presents a challenge to inclusion because the interests of the poor are increasingly excluded from the goals of policies that influence the direction of change in urban socio-technical-ecological systems. Urban elites are empowered while the poor are disempowered, as formal public–private coalitions exclude poor communities from any vision of the future of the city. Driven by a development agenda co-opted by urban elites, the remaking of urban and peri-urban places results in a mosaic of desirable and undesirable places as the environmental and economic impacts and risks of urbanization are displaced onto the peri-urban poor. Urban environmentalism tends towards alignment with exclusionary urban development projects and gentrification and the problems of peri-urban poverty and environmental degradation are cast as justification for furthering this agenda.

Simultaneously, the *blurring of boundaries* erodes the capacity and opportunity for the poor to formally challenge this co-option as the processes of decision making around the direction of socio-technical-ecological systems are becoming more exclusionary. Administrative ambiguity can result in forms of "organized irresponsibility" for managing the monitoring of environmental and infrastructural issues, particularly as they impact on poor and marginalized informal communities. This also opens unregulated space in peri-urban areas for corruption and illegal exploitation of the environment to flourish. Even as urban administrative arrangements are extended to cover peri-urban places, traditional ways of managing the environment are side-lined and disintegrate as they are replaced by formal urban institutions. Local communities find themselves powerless to control the influence of urbanization on the ecosystems upon which many of their livelihoods depend while decision making over land-use and pollution control is removed to distant state bodies with no understanding of local dynamics. Formal urban plans thus consistently fail to reflect the dynamic reality of increasingly heterogeneous communities, informal livelihoods and land-use change in peri-urban areas. The interests of the poor are excluded from policy and planning goals, and many of the poorest members of peri-urban communities lack the means to engage with formal consultations and governance processes, as they are denied the legitimacy to participate, for example, through lack of right to reside as informal in-migrants.

3.2. Barriers to experimentation

The emphasis on encouraging experimentation emerges from the view of innovation as a search process (Schot and Steinmueller, 2016, p.18). Keeping in mind the broad definition of inclusive innovation described above, experimental processes are those that allow new ways of improving the lives of the most needy to be tried out, evaluated, learned from and improved. This type of experimentation goes beyond short-term aid-funded projects to introduce new technologies to solve particular problems faced by poor communities (e.g. alternative forms of sanitation, rainwater harvesting etc.). It involves testing new configurations of socio-technical-ecological systems at the nexus of food–water–waste–energy etc. and over temporal and spatial scales significant enough to reveal any negative and positive feedbacks to the broader socio-technical regime.

Peri-urban areas are, by default, such an experiment, although driven not by the interests of the poor but by the imperatives of global capital and with little attempt to learn lessons about negative feedbacks. The type of experimentation necessary for transformative innovation in this context will need to involve reconfiguring socio-technical-ecological systems through changes in livelihood strategies among multiple groups of peri-urban and urban residents coordinated with testing and adapting decentralized food–water–waste–energy infrastructures and evolving new forms of governance to manage and enable learning from these experiments. This implies long-term close collaboration between a wide range of actors including peri-urban communities themselves, multiple state actors, private sector firms and third sector organizations as well as academic researchers.

The *rapidly changing dynamics of socio-technical-ecological systems* driven by the neoliberal restructuring of peri-urban space makes establishing such experimental collaboration very challenging. As new interactions between diverse socio-technical-ecological systems emerge across the rural–urban continuum (for example between infrastructure, industrial and peri-urban agricultural systems) unforeseen feedbacks begin to impact environmental and health outcomes for multiple groups (e.g. food safety, water quality impacts). The case studies reveal how poor and marginalized peri-urban communities face rapidly changing, risk-prone environments in which they are driven to employ a plethora of informal coping strategies and local innovations to address increasing competition for resources, access deficits, environmental degradation and marginalization, while also seeking to engage with emergent opportunities linked to urban markets (Marshall et al., 2016). Peri-urban communities have little choice but to make incremental adaptations to their livelihoods to cope with these pressures and are often faced with having to trade off reducing their material poverty against the health impacts of, for example, exposure to risks from peri-urban industrial pollution or physical impacts of intensifying agricultural labour. When the impacts of these feedbacks affect the wider urban population and reach perceived crisis levels the state responds with clean-up and control measures to address the symptoms.

These two reactionary stances preclude the kind of experimental action needed to address the underlying causes of such crises and to discover alternative configurations of socio-technical-ecological systems that limit negative feedbacks and develop synergies. These include practices such as urban waste reuse in peri-urban agriculture as part of a decentralized approach to addressing urban waste management challenges and supporting sustainable peri-urban food production to enhance urban food security. Experimentation often disproportionately benefits those firms and individuals best placed to take risks and exploit new opportunities, while further excluding the poorest people and reinforcing the pressure to stick to incremental adaptations or coping strategies that may undermine their capacity and inclination to explore alternative practices when their survival is at stake.

The *blurring of boundaries* in the peri-urban can also hinder experimentation. Newly extended urban institutional arrangements impose top down control and technocratic solutions from a distance, preventing new forms of organization and local governance emerging in response to changing local circumstances and thus disrupt local informal innovations such as wastewater reuse for peri-urban agriculture. Such informal innovations are also often ignored or assumed to have only negative consequences and may be labelled illegal. Between the weakened local institutions and the siloed municipal institutions, there is little scope for supporting informal innovations that largely remain as unsupported ad hoc coping strategies. Further, as peri-urban communities become increasingly heterogeneous and fragmented, conventional ways of engaging with grassroots innovations and mobilizations become ineffective because community identities are blurred and ambiguous and uncertainty demotivates and disempowers local groups.

3.3. Barriers to changing the direction of socio-technical regimes

The third framing of innovation policy for transformative change sees inclusion and experimentation as nurturing emergent pathways of socio-technical transformation that "challenge[s] incumbent firms and government agencies that are aligned with them (regime actors) in preserving the existing trajectory" (Schot and Steinmueller, 2016, p. 19). As such it "entails political struggles around the new goal of sustainability and it requires incumbent firms to go through processes of

strategic reorientation" (Schot and Steinmueller, 2016, p. 19). In the peri-urban context the "existing trajectory" of *neoliberal restructuring* reinforces the power of incumbent firms and feeds the co-option of environmental agendas for political ends. "Strategic reorientation" may well occur but in response to the unintended consequences of rapid urbanization rather than new societal goals.

Further, the *changing dynamics of peri-urban socio-technical-ecological systems* makes identifying the causes, and full implications, of these unintended consequences very difficult. Rapid changes and disruption of socio-technical-ecological systems in peri-urban areas generate complex feedbacks across the rural–urban continuum that are often invisible (e.g. groundwater contamination) and involve time delays (e.g. gradual accumulation of heavy metals) and cross-scale interactions (e.g. through food chains). Lacking the insights provided by experiential knowledge of peri-urban communities and hindered by traditional siloed approaches, state actors commonly adopt simplistic top-down clean-up and control responses to discrete symptoms without addressing the underlying complex causes and feedbacks across multiple systems. This presents a difficult challenge to promoting the kind of co-ordinated systemic innovations in multiple socio-technical-ecological systems required to change the direction of socio-technical regimes.

3.4. Opportunities for transformative innovation at the peri-urban interface

3.4.1. Opportunities to reframe urban sustainability debates in the face of neoliberal restructuring

Despite the challenges to inclusion discussed above there are also opportunities for reframing urban sustainability around more inclusive environmental and social justice goals. Incumbent socio-technical regimes are structurally resilient and will become destabilized when no longer able to withstand shocks and stresses (Smith and Stirling, 2010). In rapidly urbanizing Asia, the resilience of incumbent urban socio-technical regimes may be susceptible to destabilization by the multiple shocks and stresses that unchartered urban development trajectories produce. For example, feedbacks through socio-technical-ecological systems result in the emergence of unexpected hazards for populations in peri-urban and urban areas that are shared across income groups (for example, threats to fresh food and water supply and quality). These can provide promising opportunities for *direction changing* interventions if appropriate configurations of aligned actors and their capability to act can be fostered. These emergent hazards highlight shortfalls in mainstream development trajectories, while shared interest provides potential for the formation of new alliances between peri-urban and urban poor and pro-poor groups, middle-class pro-environment civil society groups and urban populations more widely. Such alliances have potential to strengthen demand among diverse stakeholders for more radical, *experimental* responses to the challenges of mainstream urbanization trajectories. Facilitating and supporting such alliances is also a key strategy in seeking to influence dominant framings of urban sustainability to be more *inclusive* of the interests and perceptions of the poor.

While new alliances in pursuit of economic growth will also emerge, they may not be as united or stable as they would appear. Direction-changing potential emerges from alliances that are able to identify and realize opportunities to challenge state authority/control by representing an alternative politics. Successful direction-changing interventions suggest the need for incremental development of sustained alliances capable of working across political scales to challenge and shift incumbent views. In these highly dynamic contexts there is also a need for a high degree of agility to adapt intervention strategies in response to shifting political interests, changing public opinion and emerging crises.

Potential direction-changing interventions across policy arenas will need to be supported by complementary interventions in research, narrative building and planning arenas; the additional "spaces" where established orthodoxies are created. Thus, alliance building for transformative change extends to the co-creation of alternative knowledge bases, and articulation of new ideas that help to reframe debates. Transdisciplinary research has a key role to play here. For a detailed discussion of pro-poor transdisciplinary research initiatives in peri-urban south Asia and their transformative potential see Marshall et al., 2018b.

3.4.2. Renegotiating governance arrangements in the context of blurred boundaries

If supported and legitimized, the growing demand for alternatives may become powerful enough to stimulate local experimentation with new forms of urbanism in peri-urban communities and development of new forms of governance and ecosystem management. Deeper engagement with peri-urban contexts reveals a unique set of opportunities in this regard. There are well-documented disjunctures between (failing) policy-driven measures to tackle peri-urban service provision and environmental management and everyday informal practices (Allen, 2013; Hofmann, 2011; Hudalah et al., 2007; Liu et al., 2010; Mehta and Karpouzoglou, 2015; Randhawa and Marshall, 2014; Webster and Muller, 2002). But it has also been possible to identify among these informal practices, those that have the potential to support pathways out of poverty for the peri-urban poor and contribute to transformative change. The same blurring of institutional boundaries and responsibilities that can be seen as barriers to transformative change through traditional established policy routes can also provide opportunities for new practices with transformative potential to emerge. For example, careful attention to informal local arrangements between the formal service providers and communities can reveal possibilities for enhancing water service provision (Randhawa and Marshall, 2014).

This potential can be better understood and nurtured by diverse actors collaborating on new practices, technologies, and organizational forms; with a focus on addressing diverse local needs while also building synergies across development goals and interest groups in the rural–urban continuum. Within such an approach, the innovative potential of poor groups can be mobilized and supported by policies targeted specifically at supporting the poor as innovators instead of passive beneficiaries (or not) of technocratic innovations. A promising example is seen in an emergent form of peri-urban environmentalism in India (Priya et al., 2017). This is "distinct from the 'environmentalism of the poor' practiced by rural and forest dwelling groups; from the dominant elite urban 'green development' practices and discourses of 'bourgeois environmentalism'; as well as from the urban politics of the poor" (Priya et al., 2017). It reflects the possibility of creating bridges across rural and urban, ideological streams, and across classes.

Contrary to popular perception, environmental activism, grassroots activities and civil society are also thriving in China and are increasingly networked across scales and with multiple state, media and international third-sector actors forming a maturing "green public culture" (Liu and Goodnight, 2016). While not yet documented, there would appear to be potential for the vulnerabilities of marginalized groups to be recognized by the strengthening green public culture, providing space for greater inclusion of such groups in innovation policy. The absence of party politics is arguably an enabler for broad, non-partisan alliances to form around shared issues between diverse social and civil society groups and state actors. Finally, the rapid growth of urban markets, an increasingly environmentally conscious urban middle-class, broad access to the internet and smart phones, strong homegrown social media platforms and the continuing importance of the informal economy across the rural–urban continuum provide growing opportunities for new economic and social relationships with very little external interference from the state, such as in the example of alternative food networks in China (Si et al., 2015).

3.4.3. Reconfiguring socio-technical-ecological interactions

Although the rapid and unpredictable changes in socio-technical-ecological systems interactions at the peri-urban interface create a particular challenge for transformative innovation they do provide an opportunity to learn rapidly from changes in livelihood patterns and socio-technical-ecological practices if such experimental endeavours are appropriately supported. For example, in Wuhan there are cases of migrant peri-urban vegetable farmers who have found innovative ways of organizing themselves and adapting agricultural technologies to create more sustainable forms of peri-urban agriculture, such as a medium-scale integrated farming system in which pig manure was converted into nutrient rich fertilizer through a bio-digester, while plant waste from harvested vegetables was used as feed supplements for the pigs. This allowed for a highly productive farming system with reduced chemical fertilizer and pesticide inputs. The scale of production and a direct link to a retail market enabled the farm to be sited further away from the urban centre than one would normally find vegetable production, thus providing a more stable long-term use of the land. Identifying, learning from and replicating such experiments holds significant potential for developing pro-poor transformative innovations.

Further, because socio-technical-ecological interactions are already undergoing transformation accompanied by increasingly obvious negative consequences for local environmental and human health, alternatives that mitigate these impacts and provide synergies between multiple systems are more likely to gain traction. As scientific evidence accumulates around these potential alternatives the credibility of the dominant trajectory of urbanization can be undermined and new approaches to policy and planning begin to gain enough legitimacy to challenge the status quo.

Promoting such complex experiments is unlikely to be possible using a niche management approach in which new technologies and organizational innovations are given a safe space in which to be formally tested and scaled up. Peri-urban communities depend upon multiple informal innovations that form coping strategies. These strategies often involve difficult trade-offs between different dimensions of poverty (Chambers, 2007) and rely on informal markets and governance arrangements. Far from disrupting the socio-technical regime, they are more readily seen as simply enabling the poor to survive in its shadow. Under such conditions, the potential for innovative reconfigurations of socio-technical and social-ecological systems will be very hard to discern without engaging with the experiential knowledge of peri-urban communities themselves over the long-term and through forging diverse alliances among community, activist, scholar, policy and private sector stakeholders. This suggests a need to problematize the idea of protected niches in these dynamic, informal contexts, with a view to considering if and how adapted niche management approaches could be effective in supporting processes of transformative innovation.

4. Lessons from the peri-urban interface for the transformative innovation agenda

We recognize transitional peri-urban spaces as key hotspots or “frontiers for sustainability” (Marshall, 2016) where the acute challenges of rising inequalities, exclusion and the degradation of ecosystems are accompanied by new opportunities for innovation and for building synergies across the urban–rural continuum (Agarwal et al., 2015; Marshall and Randhawa, 2017; Priya et al., 2017; Randhawa and Marshall, 2014). Innovation for sustainability is frequently discussed in relation to transitions in socio-technical systems in which innovations in product, process and practice originate in niches and may, through scaling up, generate systemic innovations that transform one stable socio-technical regime into another. In the context of rapidly urbanizing peri-urban settings, however, the socio-technical regime is in flux. It is characterized by ongoing and rapid changes in livelihoods, populations and land-use; shifting configurations of and interactions between social-ecological and socio-technical systems; and ambiguous governance and institutional arrangements. The challenge for establishing processes of transformative innovation in such contexts is that the rules of the game and the game players are constantly changing. In the context of dominant socio-technical regimes that are often reinforcing inequalities, the effort to support inclusion and experimentation and to challenge dominant trajectories through innovation processes is not only going against the grain of mainstream urban development but is also highly political.

We are framing innovation not in terms of firms or innovation systems but as the activity of alliances that mobilize resources, imaginations, practices and technologies in novel ways for social goals. These social goals may be more or less progressive or oppressive, growth or greening focused, pro-poor or pro-elite and defined at different scales from that of the household or community through to national and global. Transformative innovation in the context of urbanization means innovation that enables/contributes to sustainable urban transformation through new configurations of connected socio-technical-ecological systems (of housing, agri-food, sanitation, drinking water, recreation, mobility/transportation, health).

Promoting inclusive, experimental and direction-changing innovation processes means more than simply providing the opportunity for diverse stakeholders to formally influence the innovation process (e.g. through new institutional and governance arrangements for participatory decision making). It requires recognizing and seeking to rebalance the inequalities in power and knowledge between individuals, communities, governmental and non-governmental organizations, universities and firms as they enact new ways of achieving their diverse and sometimes conflicting aims.

Support for transformative innovation in this context requires transformation of knowledge systems (Marshall et al., 2018b) to incorporate experiential, embedded knowledge of marginalized peri-urban communities alongside diverse but purposeful alliances across formal-informal, multiple sectors and scientific disciplines responding to social demand for knowledge. This is different from the innovation systems approaches that tend to emphasize the strengthening of interactions between, and capacities within, the formal institutions that make up innovation systems driven by global and national markets and commercial demand for knowledge.

There is empirical evidence of the emergence of new forms of alliance building with the potential to contribute to transformative innovation in this way. Our examples illustrate the importance of long-term alliances, embedded in grounded community experiences, which continue to evolve and to develop the agility to be responsive to rapidly changing contexts and opportunities for influence. Local politics and power dynamics are undoubtedly integral to the manner in which such alliances are formed, evolve, disintegrate and change in nature around particular urban development pathways, and this is an important area for further study.

The wider political economy, and level of state control are also influential in shaping the transformative potential of grassroots initiatives (and associated alliance building) for urban sustainability. However, in informal settings with innovations led by the poor, the extent and degree of that influence may be hard to predict. As we have discussed, the absence of party politics in China is arguably an enabler for the formation of broad non-partisan alliances of diverse civil society groups and state actors with shared goals. While the transformative potential of informal innovation by communities of the poor in India is partly enabled by institutional ambiguity and lack of formal regulations, coupled with the emergence of new forms of peri-urban environmentalism that link civil society groups across income groups and the rural–urban divide. This suggests real direction-changing potential.

5. Conclusion

Enhanced understanding of, and engagement with, transitional peri-urban contexts is an essential consideration in establishing sustainable

city-region development trajectories. These rapidly changing contexts provide some unique opportunities for learning, and for evaluation of alternative development pathways as they unfold. Here the realization of transformative innovation policy is an enticing prospect, with potential for major and widespread impact. Focusing on distinctive peri-urban features, and their enabling and constraining characteristics, we have drawn insights for how inclusion, experimentation and direction changing processes are conceptualized within the transformative innovation policy agenda.

In the face of the global pattern of exclusionary urbanization, inclusive innovation processes must involve a foregrounding of the politics of land-use changes and environmental interventions as they play out. In doing so, implications for poor and marginalized groups must be recognized, alongside the experiential embedded knowledge of these communities as partners in adaptive policy making and planning strategies towards more sustainable futures.

A diversity of informal and decentralized innovations interact with formal systems, but they often go unrecognized in their potential to reconfigure socio-technical and social-ecological interactions. We argue that the direction-changing aspects of transformative innovation in these deeply uncertain, contested and dynamic contexts are unlikely to emerge from the identification and scaling up of niche activities (albeit this will play a role); but they will evolve through the enhanced capacity of new alliances of actors to influence dominant framings of urban development, and to capture windows of opportunity. This often occurs when there is an unforeseen crisis or shock to the incumbent socio-technical regime. Communities of interest are building, and with them the potential to realize synergies between apparently conflicting urban development priorities. However, despite cause for optimism, the global financial imperative for urban real-estate development remains an overarching threat to widespread transformative change in these contexts.

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References

Agarwal, R., Marshall, F., Pandey, P., Randhawa, P., 2015. Rethinking Urban Waste Management in India (Policy Brief). STEPS Centre, New Delhi. http://steps-centre.org/wp-content/uploads/Policy-Brief-April-2015.pdf.

Agrawal, M., Singh, B., Rajput, M., Marshall, F., Bell, J.N.B., 2003. Effect of air pollution on peri-urban agriculture: a case study. Environ. Pollut. 126, 323–329.

Allen, A., 2013. Water provision for and by the peri-urban poor: public-community partnerships or citizens coproduction? In: Vojnovic, I. (Ed.), Urban Sustainability: A Global Perspective. Michigan State University Press, East Lancing, MI.

Allen, A., 2014. Peri-urbanisation and the political ecology of differential sustainability. In: Parnell, S., Oldfield, S. (Eds.), A Routledge Handbook on Cities of the Global South. Routledge, London/New York.

Amerasinghe, P., Bhardwaj, R.M., Scott, C., Jella, K., Marshall, F., 2013. Urban Wastewater and Agricultural Reuse Challenges in India. IWMI Research Report No. 147. International Water Management Institute, Colombo, Sri Lanka.

Baviskar, A., 2010. Indian environmental politics: an interview. Transform. Cult. eJournal 5 (1).

Bryden, J., Gezelius, S.S., Refsgaard, K., Sutz, J., 2017. Inclusive innovation in the bioeconomy: concepts and directions for research. Innovation Dev. 7, 1–16. https://doi.org/10.1080/2157930X.2017.1281209.

Bugliarello, G., 1994. Technology and the city. In: Fuchs, R.J., Brennan, E., Chamie, J., Lo, F., Uitto, J.I. (Eds.), Mega-City Growth and the Future. United Nations University Press, Tokyo, New York, Paris, pp. 131–146.

Chambers, R., 2007. Poverty Research: Methodologies, Mindsets and Multidimensionality. IDS Working Paper No. 293. Institute of Development Studies, Brighton, UK.

Chataway, J., Hanlin, R., Kaplinsky, R., 2014. Inclusive innovation: an architecture for policy development. Innovation Dev. 4, 33–54.

Dolley, J., 2017. Sustainability, Resilience and Governance of an Urban Food System: A Case Study of Peri-Urban Wuhan (Doctoral Thesis (PhD)). URL. University of Sussex, Brighton, UK. http://sro.sussex.ac.uk/66462/.

Dupont, V.D.N., 2007. Conflicting stakes and governance in the peripheries of large Indian metropolises: an introduction. Cities 24, 89–94. https://doi.org/10.1016/j.cities.2006.11.002.

Dupont, V.D.N., 2011. The dream of Delhi as a global city. Int. J. Urban Reg. Res. 35, 533–554. https://doi.org/10.1111/j.1468-2427.2010.01027.x.

Ernstson, H., van der Leeuw, S.E., Redman, C.L., Meffert, D.J., Davis, G., Alfsen, C., Elmqvist, T., 2010. Urban transitions: on urban resilience and human-dominated ecosystems. AMBIO 39, 531–545. https://doi.org/10.1007/s13280-010-0081-9.

Gaston, K.J., Ávila-Jiménez, M.L., Edmondson, J.L., 2013. Review: managing urban ecosystems for goods and services. J. Appl. Ecol. 50, 830–840. https://doi.org/10.1111/1365-2664.12087.

George, H., 1904. Progress and Poverty, 4th ed. Doubleday Page, New York.

Harvey, D., 1973. Social Justice and the City. Edward Arnold, London.

Hofmann, P., 2011. Falling through the net: access to water and sanitation by the peri-urban water poor. Int. J. Urban Sustainable Dev. 3, 40–55. https://doi.org/10.1080/19463138.2011.577274.

Hudalah, D., Winarso, H., Woltjer, J., 2007. Peri-urbanisation in East Asia: a new challenge for planning? Int. Dev. Plann. Rev. 29, 503–519.

Karpouzoglou, T., Zimmer, A., 2012. Closing the gap between “expert” and “lay” knowledge in the governance of wastewater: lessons and reflections from New Delhi. IDS Bull. 43, 59–68.

Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A.C., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., Folke, C., Olsson, P., 2012. Transforming innovation for sustainability. Ecol. Soc. 17. https://doi.org/10.5751/ES-04933-170211.

Liu, J., Goodnight, T.G., 2016. China’s green public culture: network pragmatics and the environment. Int. J. Commun. 10, 5535–5557.

Liu, Y., He, S., Wu, F., Webster, C., 2010. Urban villages under China’s rapid urbanization: unregulated assets and transitional neighbourhoods. Habitat Int. 34, 135–144. https://doi.org/10.1016/j.habitatint.2009.08.003.

Ma, L.J.C., 2002. Urban transformation in China, 1949–2000: a review and research agenda. Environ. Plann. A 34, 1545–1569. https://doi.org/10.1068/a34192.

Marshall, F., 2016. Recognizing sustainability frontiers in the peri-urban. South Asian Water Stud. 5 (3).

Marshall, F., Randhawa, P., 2017. India’s Peri-Urban Frontier: Rural–Urban Transformations And Food Security. International Institute for Environment and Development, London. http://pubs.iied.org/10794IIED.

Marshall, F., Agarwal, R., Lintelo, D.te, Bhupal, D.S., Singh, R.P.B., Mukherjee, N., Sen, C., Poole, N., Agrawal, M., Singh, S.D., 2003. Heavy Metal Contamination of Vegetables in Delhi (Executive Summary of Technical Report). UK Department for International Development, London. http://toxicslink.org/docs/06102_Finding_of_Heavy_Metal_Contamination_of_Vegetables.pdf.

Marshall, F., Waldman, L., MacGregor, H., Mehta, L., Randhawa, P., 2009. On the Edge of Sustainability: Perspectives on Peri-Urban Dynamics. STEPS Working Paper 35. STEPS Centre, Brighton. http://www.ids.ac.uk/publication/on-the-edge-of-sustainability-perspectives-on-peri-urban-dynamics.

Marshall, F., Scharlemann, J., Waldman, L., Priya, R., Punia, M., Desai, P., Amerasinghe, P., 2016. Risks and Responses to Urban Futures: Integrating Peri-Urban/Urban Synergies into Urban Development Planning for Enhanced Ecosystem Services Benefits. ESPA Funded Project. http://steps-centre.org/project/urban-futures.

Marshall, F., Dolley, J., Randhawa, P., Bisht, R., Priya, R., Waldman, L., Scharlemann, J., Shamma, C., Devi, C., Saharia, R., Oxley, N., 2017. Why Peri-Urban Ecosystem Services Matter for Urban Policy (Policy Briefing). STEPS Centre, Brighton. http://steps-centre.org/wp-content/uploads/2017/03/Peri_urban_Ecosystem_briefing.pdf.

Marshall, F., Dolley, J., Bisht, R., Priya, R., Waldman, L., Amerasinghe, P., Randhawa, P., 2018a. Ecosystem services and poverty alleviation in urbanising contexts. In: Schreckenberg, K., Mace, G., Poudyal, M. (Eds.), Ecosystem Services and Poverty Alleviation: Trade-Offs and Governance. Routledge, London, pp. 111–125.

Marshall, F., Dolley, J., Priya, R., 2018b. Transdisciplinary research as transformative space making for sustainability: Enhancing pro-poor transformative agency in peri-urban contexts. Ecol. Soc. 23 (3), 8. https://doi.org/10.5751/ES-10249-230308.

Martin, B.R., 2016. Twenty challenges for innovation studies. Sci. Public Policy 43, 432–450.

McGee, T.G., 2008. Managing the rural–urban transformation in East Asia in the 21st century. Sustainability Sci. 3, 155–167. https://doi.org/10.1007/s11625-007-0040-y.

Mehta, L., Karpouzoglou, T., 2015. Limits of policy and planning in peri-urban waterscapes: the case of Ghaziabad, Delhi, India. Habitat Int. 48, 159–168. https://doi.org/10.1016/j.habitatint.2015.03.008.

Narain, V., Nischal, S., 2007. The peri-urban interface in Shahpur Khurd and Karnera. India. Environ. Urbanization 19, 261–273. https://doi.org/10.1177/0956247807076905.

Navlakha, G., 2000. Urban pollution: driving workers to desperation. Econ. Political Weekly 35, 4469–4471.

Priya, R., Bisht, R., Randhawa, P., Arora, M., Dolley, J., McGranahan, G., Marshall, F., 2017. Local Environmentalism in Peri-Urban Spaces in India: Emergent Ecological Democracy? STEPS Working Paper 96. STEPS Centre, Brighton. https://steps-centre.org/publication/local-environmentalism-peri-urban-spaces-india-emergent-ecological-democracy/.

Randhawa, P., Marshall, F., 2014. Policy transformations and translations: lessons for sustainable water management in peri-urban Delhi, India. Environ. Plann. C: Government Policy 32, 93–107. https://doi.org/10.1068/c10204.

Roy, D., 2004. From home to estate. Seminar 53, 68–74.

Schot, J., Kanger, L., 2016. Deep Transitions: Emergence, Acceleration, Stabilization and Directionality. Working Paper No. SWPS 2016-15. SPRU. University of Sussex, Brighton, UK. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2834854.

Schot, J., Steinmueller, W.E., 2016. Framing Innovation Policy for Transformative Change: Innovation Policy 3.0 - Draft Version 2 (Draft Working Paper). Science Policy Research Unit (SPRU). University of Sussex, Brighton, UK.

Schumpeter, J.A., 1942. Capitalism, Socialism and Democracy. Harper & Brothers, New York.

Sharma, R.K., Agrawal, M., Marshall, F., 2006. Heavy metal contamination in vegetables grown in wastewater irrigated areas of Varanasi, India. Bull. Environ. Contam. Toxicol. 77, 312–318. https://doi.org/10.1007/s00128-006-1065-0.

Sharma, R.K., Agrawal, M., Marshall, F.M., 2008. Heavy metal (Cu, Zn, Cd and Pb) contamination of vegetables in urban India: a case study in Varanasi. Environ. Pollut. 154, 254–263. https://doi.org/10.1016/j.envpol.2007.10.010.

Si, Z., Schumilas, T., Scott, S., 2015. Characterizing alternative food networks in China. Agric. Hum. Values 32, 299–313. https://doi.org/10.1007/s10460-014-9530-6.

Simon, D., 2008. Urban environments: issues on the peri-urban fringe. Annu. Rev. Environ. Resour. 33, 167–185.

Singh, A., Sharma, R.K., Agrawal, M., Marshall, F., 2009. Effects of wastewater irrigation on physicochemical properties of soil and availability of heavy metals in soil and vegetables. Commun. Soil Sci. Plant Anal. 40, 3469–3490. https://doi.org/10.1080/00103620903327543.

Singh, A., Agrawal, M., Marshall, F.M., 2010a. The role of organic vs. inorganic fertilizers in reducing phytoavailability of heavy metals in a wastewater-irrigated area. Ecol. Eng. 36, 1733–1740. https://doi.org/10.1016/j.ecoleng.2010.07.021.

Singh, A., Sharma, R.K., Agrawal, M., Marshall, F., 2010b. Health risk assessment of heavy metals via dietary intake from the wastewater irrigated site of a dry tropical area of India. Food Chem. Toxicol. 48, 611–619. https://doi.org/10.1016/j.fct.2009.11.041.

Smith, A., Stirling, A., 2010. The politics of social-ecological resilience and sustainable socio-technical transitions. Ecol. Soc. 15, 11.

Soete, L., 2013. From emerging to submerging economies: New policy challenges for research and innovation. Sci. Technol. Innovation Policy Rev. 4, 1–13.

Stirling, A., 2008. “Opening up” and “closing down”: power, participation, and pluralism in the social appraisal of technology. Sci. Technol. Hum. Values 33, 262–294. https://doi.org/10.1177/0162243907311265.

STEPS Centre and Sarai, 2010. Contesting sustainabilities in the peri-urban interface (STEPS Research report). STEPS Centre, Brighton, UK [online] URL: https://steps-centre.org/publication/contesting-sustainabilities-in-the-peri-urban-interface/.

Van der Have, R.P., Rubalcaba, L., 2016. Social innovation research: an emerging area of innovation studies? Res. Policy 45, 1923–1935. https://doi.org/10.1016/j.respol.2016.06.010.

Waldman, L., Bisht, R., Saharia, R., Kapoor, A., Rizvi, B., Hamid, Y., Arora, M., Chopra, I., Sawansi, K., Priya, R., Marshall, F., 2017. Peri-urbanism in globalizing India: a study of pollution, health and community awareness. Int. J. Environ. Res. Public Health 14, 980. https://doi.org/10.3390/ijerph14090980.

Webster, D., Muller, L., 2002. Challenges of Peri-Urbanization in the Lower Yangtze Region: The Case of Hangzhou-Nimbo Corridor. Discussion Paper. Asia Pacific Research Center. Stanford University, Stanford, CA.

Zehavi, A., Breznitz, D., 2017. Distribution sensitive innovation policies: conceptualization and empirical examples. Res. Policy 46, 327–336. https://doi.org/10.1016/j.respol.2016.11.007.